Historic, Archive Document

Do not assume content reflects current
scientific knowledge, policies, or practices.

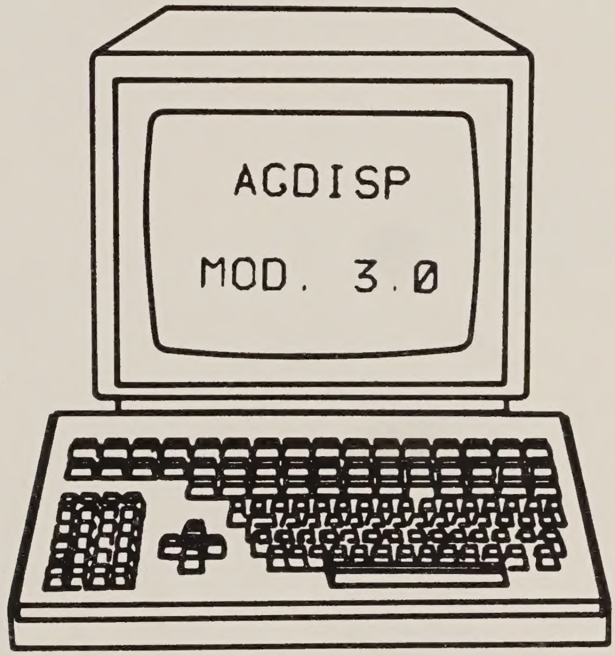
Reserve
aSB953
.T469
1986

Forest Service

Equipment
Development
Center

Missoula, MT

User Manual Extension For The Computer Code AGDISP MOD 3.0



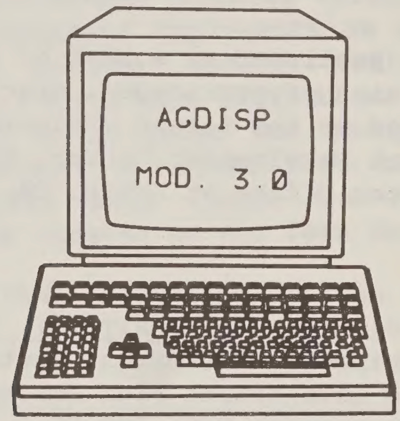
February 1986
3400—Forest Pest Management
8634 2802

United States
Department of
Agriculture

NATIONAL
AGRICULTURAL
LIBRARY

Advancing Access to
Global Information for
Agriculture

User Manual Extension For The Computer Code AGDISP MOD 3.0



Prepared by
Milton E. Teske

Continuum Dynamics, Inc.
P. O. Box 3073
Princeton, NJ 08540

Prepared for
U. S. Department of Agriculture
Forest Service
Equipment Development Center
Missoula, MT 59801

Robert B. Ekblad
Project Leader

February 1986

(This work was done under contract 53–0343–3–00716, February 1985)

Pesticide Precautionary Statement

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

Caution: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

FOREWORD

This report is published as a part of the USDA Forest Service program to improve aerial application of pesticides, specifically by using pesticides and delivery systems tailored to the forest environment. The program is conducted jointly by the Equipment Development Center, Missoula, MT, and the Forest Pest Management Staff, Washington Office at Davis, CA, under the sponsorship of State and Private Forestry.

Details of the aerial application improvement program are explained in two Forest Service reports, A Problem Analysis: Forest And Range Aerial Pesticide Application Technology (Equipment Development Center Rpt. 7934 2804, July 1979, Missoula, MT) and Recommended Development Plan for An Aerial Spray Planning and Analysis System (Forest Pest Management Rpt. FPM 82-2, February 1982, Davis, CA).

A system of computer models has been developed to optimize spray program design and operation and assess environmental risk posed by aerial spray operations. AGDISP is one of these models, and this user's manual covers the most recent version of AGDISP, Mod 3.0.

AGDISP was developed under the leadership of the National Aeronautics and Space Administration with support by the Forest Service to include special forest spray conditions.

When NASA's Agricultural Aviation Program was terminated, the Forest Service continued to support and direct further development and improvements of the AGDISP model.

The following changes and additions have been incorporated into Mod 3.0:

1. Helicopter modeling with transition to rolled-up vortices.
2. AGLINE calculations as a menu option to AGPLOT.
3. Discrete wind profile option.
4. Non-zero deposition height.
5. Composite droplet deposition plots.
6. Canopy penetration by helicopter downwash.
7. Droplet diameter time history plot.

The Mod 3.0 is operational on the USDA Univac 1108 at Fort Collins and is installed with DISSPLA graphics instead of PLOT 10.

A report on Technological Applications and Support Project TE02P18, Technical Services, Forest Pest Management, funded by the Forest Pest Management Staff, State and Private Forestry.

SUMMARY

The AGDISP computer code predicts the motion of agricultural material released from aircraft, including the mean position of the material and the position variance about the mean as a result of turbulent fluctuations. Developed under joint sponsorship by NASA and USDA, this code operates efficiently and is user-friendly, with many of its features validated against wind-tunnel and flight test data. This document represents an extension of the Mod 2.0 User Manual (Ref. 1) to include further refinements and enhancements. Much of the details of Ref. 1 have been left intact and are not repeated here, even though the computer environment has changed and the enhancements have altered some code structure and some test case results. However, those areas that directly impact code usage are reviewed and explained. Application of the Mod 3.0 code version to the Fort Collins Univac 1108 system is discussed in Ref. 2.

TABLE OF CONTENTS

1. CURRENT AGDISP OPTIONS

The flow field options available in Mod 3.0 are the following:

Fixed-Wing Fully Rolled-Up Tip Vortices

If roll-up of trailing vorticity can be approximated as occurring immediately downstream of the wing, the mean velocity field that results may be simply characterized by the aircraft semispan, circulation and load distribution (either rectangular or triangular).

Fixed-Wing Betz Roll-Up

Time integration of trailing vorticity rolling-up into multiple discrete vortices and the influence of the increasing vortex strength and of the unrolled vortex sheet are available. The approach is based on the Betz methodology and involves specifying the wing load distribution.

Propeller

The propeller model is an adaptation of actuator-disk theory and involves knowing the basic propeller characteristics of engine efficiency, shaft rpm, blade radius, aircraft drag coefficient, and aircraft wing planform area. Turbulence effects due to the propeller slipstream are included.

Helicopter in Forward Advance

The helicopter flow field is modeled as a skewed hover wake, following actuator-disk theory, transitioning to a rectangularly-loaded, fully rolled-up vortex pair.

Mean Background Crosswind

Atmospheric crosswind in the (y,z) plane is parameterized as a neutral logarithmic velocity profile dependent upon knowing the crosswind at a height and the surface roughness (generally characterized as 1/30 of the physical height of the surface covering). Alternately, the crosswind may be specified as a function of height above the surface.

Plant Canopy

When a plant canopy, such as a stand of fir trees, comprises the surface features, the plant area density of the canopy may be entered into the AGDISP code. Modifications to surface roughness, turbulence and particle paths within the canopy are made consistent with the presence of the canopy.

Superequilibrium Turbulence

Local background turbulence level may be simply specified by specifying the crosswind velocity, by fixing a constant value (typically one percent of the mean wind speed), or by optioning the AGDISP code to compute the turbulence field consistent with the given mean velocity field. This option

solves the nonlinear, algebraic equations of superequilibrium turbulence to determine the local atmospheric turbulent structure.

Terrain

A nonhorizontal, level surface may be assumed.

WAKE Results

The AGDISP code has been fitted with the option of entering any externally-computed mean velocity and turbulence field, as long as the computer-generated plot file corresponds to the format specified in Section 3 of this manual.

A discussion of the details of the modeling for the above options may be found in Ref. 3. Mod 3.0 extensions include generalization of the crosswind velocity profile, and, principally, a significant change in the helicopter model and its interaction with the canopy. Previously, the helicopter model partitioned the flowfield into a propeller-like hover downwash and a rectangularly-loaded, fully rolled-up vortex pair using the inputted forward advance ratio:

$$FW = 2\rho\pi R^2 w^2 \qquad \text{(hover downwash)}$$

$$(1 - F)W = 2\rho RU\Gamma \qquad \text{(vortex pair)}$$

where

W = aircraft weight
ρ = atmospheric density
R = rotor blade radius
w = induced downwash velocity
U = freestream velocity
Γ = vortex pair circulation strength

and

$$F = 1 - \mu$$

where μ is the helicopter forward advance, the ratio of U to the rotational tip speed of the rotor blades. Recent theoretical work with helicopter modeling in forward advance (Ref. 4) suggests that the helicopter wake flowfield begins as a downwash field but quickly (generally within two blade revolutions) transitions into a vortex pair. This dynamic transition is built into the Mod 3.0 code version by redefining F to be:

$$F = \exp[-k\mu(\frac{x\Gamma}{\pi R^2 U})]$$

where x is the distance downstream of the particle release point. The nondimensional factor in the exponent is obtained from an examination of airplane roll-up (Ref. 5) while the presence of μ acknowledges the significant importance of forward advance. The constant k relates helicopter roll-up (around a circumference at the blade tip with multiple blades) to fixed-wing roll-up. Predicted results from Ref. 4 suggest that k is about equal to 125. This revised model for F awaits confirming data tests by the Forest Service.

The transition built into the current model implies that the flowfield behind a helicopter will always begin as a downwash field and will always become a vortex pair. This vortex pair will be influenced by the canopy following the analysis described in Ref. 3. Mod 3.0 has added a canopy influence to the downwash portion of the helicopter flowfield by modifying the position of the dividing streamline (separating the downwash field and the ambient air) to account for the effective thickness of the plant area density. This correction elevates the dividing streamline and includes more of the flowfield within the helicopter downwash influence. Within the canopy itself the imposed flow velocity will be nearly horizontal.

The dividing streamline model discussed in Ref. 3 was developed assuming the helicopter was always in ground effect. The current AGDISP model has been further modified to permit simulations out of ground effect. In this case, the helicopter blade is connected by a streamtube to the assumed height where ground effect begins (taken as two blade radii above the surface). This tube extends above the rotor plane with a tube radius equal to the blade radius, and below the rotor plane with a tube radius increasing as a result of turbulent diffusion down to the height where ground effect begins. The vortex pair created by the helicopter is assumed to follow the dividing streamline. Each vortex will move under induced velocity effects from the other vortex, the image pair, any crosswind velocity, and one-half of the rotor-induced velocity along the dividing streamline.

2. AGDISP OPERATION

The AGDISP code consists of two programs: AGDISP for establishing the desired background fields and computing the particle trajectories, and AGPLOT for plotting the resulting particle solutions. These programs are configured as interactive programs reading their needed input data from disk files and writing output to the terminal. AGDISP reads an input file of data cards (valid cards are discussed in Section 3), types information to the terminal as the run proceeds, generates printed output in a separate file, stores particle trajectory information in a plot file for subsequent plotting, and reads WAKE plot file results from a separate data file (if invoked). AGPLOT reads the desired particle plot file and interactively questions the user to supply necessary scaling data for the plot construction.

The AGDISP code reads and processes the input data disk file, causing termination of the program if errors are discovered or needed cards are missing. Initialization follows: particle locations and velocities, vortex strength, Betz roll-up, plant canopy, crosswind velocity profile, WAKE plot file. The particle equations are then integrated repeatedly until one of three termination conditions occurs:

1. maximum simulation time is reached;

2. all of the particles are deposited on the surface; or

3. all of the particles are discarded at the evaporation cutoff diameter (if invoked).

Each integration step in turn includes the following:

1. updating the background mean velocity and turbulence fields by the WAKE plot file, Betz roll-up, vortex motion, or plant canopy;

2. equation system predictor of the particle equations;

3. two equation system correctors of the particle equations; and

4. incremental file save of the particle results for subsequent plotting by AGPLOT.

Solution of the particle equations is by a modified predictor-corrector scheme employing two correctors to enhance solution accuracy. A fixed time step size is determined by the program knowing the particle and evaporation time scales. The algorithm involved was selected to give accurate results to the particle equations without impacting computer time involved.

Nonetheless, AGDISP is flexible enough to admit a wide variety of input conditions, some of which may demand increased computer time. In these cases, "$$$ WARNING" messages will be used to flag such events. The messages that may currently appear are the following:

1. SMALL PARTICLE INVOKED occurs whenever the simulation follows

particles of 50 microns or less. In this case, the particle time scale can become small, and the computing needs, substantial.

2. SUPEREQUILIBRIUM TURBULENCE INVOKED occurs in those instances where the desired turbulence background solves the superequilibrium equations. This option appears to be most severe, in general doubling the computer needs of the AGDISP code.

3. EVAPORATION INVOKED occurs because the equation time step must be adjusted downward as the particles become smaller to account for evaporation effects. The comments of message 1 then apply.

4. MANY PARTICLES INVOKED occurs whenever the number of particles to be followed exceeds ten. Ten is an arbitrarily chosen number, perhaps too low, but serves to warn to user that program solution is linear; i.e., twenty particles take twice as long as ten particles.

5. LONG SIMULATION TIME INVOKED occurs whenever the maximum expected simulation time normalized by particle size exceeds a given level. This level may also be low, but it nonetheless serves the same purpose as the level in message 4.

6. WAKE PLOT FILE INVOKED is written when this option is used because the overhead associated with reading an externally constructed data file may vary greatly with the size of the file.

The current limits of the AGDISP code are the following:

1. All of the idealized background mean velocity and turbulence fields are for neutral environments. The inputted crosswind velocity profile will be interpreted as locally neutral.

2. The total number of particles that can be included in the simulation cannot exceed 60. The error message INCORRECT NUMBER OF PARTICLES will be invoked and AGDISP will terminate.

3. The Betz roll-up cannot enter more than 100 discrete circulation values along the wing. The error message ERROR IN CIRCULATION DATA INPUT will be invoked and AGDISP will terminate.

4. The Betz roll-up procedure cannot handle more than four discrete vortices rolling-up on each wing. In this case, the error message BETZ WILL ROLL-UP MORE THAN 4 VORTICES will be invoked and AGDISP will terminate.

5. The plant canopy input data cannot permit more than 100 discrete entries to define the canopy vertical profile shape. The error message ERROR IN PLANT AREA DENSITY INPUT will be invoked and AGDISP will terminate.

6. The discrete crosswind velocity data cannot permit more than 100 entries to define the velocity profile. The error message ERROR IN CROSSWIND VELOCITY INPUT will be invoked and AGDISP will terminate.

The AGPLOT code interactively plots the AGDISP plot file contents on Tektronix terminals using the Fort Collins DISSPLA plotting package. Input to AGPLOT is the desired plot file. After scanning the file AGPLOT offers the current menu of plotting options available to the user, who then determines the options to invoke. The plots are generated in a temporary, machine-language data file. After exiting the AGPLOT code the user invokes DISSPLA to dump the plots from the data file to the terminal. AGPLOT details are discussed in Section 4.

3. AGDISP INPUTS

This section of the AGDISP User Manual details the input cards to the code. All data entry is in free format, wherein card data is separated by commas or blank spaces. This convenience offers ease of formatting the data but requires that every data card used have all of its data values present, even if they are zero. Unless noted below as integer values, data is entered as real numbers (with decimal points). The MKS system is used throughout.

Input data must be present in a reader file attached to unit 4, interactive output is written to the terminal on unit 6, printed output is written to a file on unit 9, particle trajectory data results are written to a data output file on unit 8 (for later plotting by AGPLOT), and WAKE plot file data is entered on unit 10. All card input data is echoed on the terminal, improper data is flagged, and missing data cards are exposed. All data cards begin with a four-digit identification in columns 1-4, with the rest of the data in free format. The order of the cards is important and must follow ever-increasing identification numbers. The AGDISP code has been programmed to verify this order. In addition, certain available options are inconsistent with each other. The AGDISP code has been programmed to trap these inconsistencies, with the message CARD ORDER INCONSISTENT AT CARD NUMBER followed by the offending card when an error is detected. Unsupported cards are flagged with the message AGDISP CODE DOES NOT SUPPORT CARD NUMBER, while missing data cards are flagged with INPUT DOES NOT FULLY INITIALIZE AGDISP RUN. With free format there exists the chance that all necessary data does not appear on the appropriate card; in this case, the AGDISP code will run out of data cards before it rationalizes all of its data pointers. The error message will read INSUFFICIENT DATA BEFORE CARD following the card where data ended. This error message is perhaps the most devious because it may require a detailed examination of <u>all</u> data cards to determine the missing data.

On the other hand, because all of the data is echoed on the termin error messages are traceable in a systematic manner. A careful check shou be made the first time a new case is started, and at least until the user i confident of the program input requirements. Only by looking at what the program thinks is inputted will the user be able to verify that what was inputted was correct. In almost all cases, the code makes <u>no</u> check of input validity, either signs or magnitudes. Gravity is built into the program as 9.8 m/sec^2 . Every AGDISP run requires the entry, at least, of cards 0010, 0020, 0050 and 0060.

Detailed description of the currently available data cards follows, including the special error messages they invoke.

Card 0000 is a comment card, any number of which may be placed anywhere in the input deck. The 76 columns of comment are merely reproduced on the terminal.

Card 0010 is the program card requiring two entries. The first is the maximum time in seconds for the simulation to run, a time which will be shortened if all of the particles impact the surface or are discarded at the evaporation cutoff before the maximum time is

reached. The other entry is the simulation plane entry (integer) configuring either a half-plane $(y > 0)$ solution (a value of 1) or a full plane $(-\infty < y < +\infty)$ solution (a value of 2). The full plane solution should be invoked if crosswind, propeller or terrain exists. Single particle release without an aircraft should use the full plane value of 2. Card 0010 is a required input card.

Card 0011 is the printing/plotting control card requiring two positive (integer) entries. Under normal operation AGDISP output is generated at appropriate intervals to the printer and the plot file. The first entry on this card modifies the default printing interval of the time histories of the particles. Entry of a number greater than 1 increases the printing interval (the plotting interval cannot be altered). Default value is 1; to turn off printing requires an entry of 0. The second entry invokes plot file saving of the time histories of the driving trajectories, and controls the interval of printing these time histories. The driving trajectories are those associated with the centers of vortices, the center of the propeller and the center of the helicopter rotor disk (whenever any are present in a particular run). Any value for this entry invokes additional plot file output, to permit subsequent plotting of the driving trajectories by AGPLOT. A number greater than 1 increases the printing interval. Default value is 0. Card 0011 is an optional card.

Card 0015 is the terrain slope angle card requiring the entry of local ground slope in degrees. A positive terrain angle raises the right side of the surface as viewed from behind the aircraft, with the origin remaining along the initial aircraft vertical centerline. The terrain is characterized by a locally straight surface so that all of the simplified flow field options in AGDISP remain available. A full plane solution is necessary. Canopy and crosswind effects remain parallel to the tilted surface. This feature cannot be invoked with the WAKE plot file option. Card 0015 is an optional card.

Card 0020 is the aircraft characteristics card requiring six entries. The first is the mean velocity flag (integer), taking one of six values:

3 denotes helicopter entry;

2 denotes a rectangularly loaded, fully rolled-up tip vortex;

1 denotes a triangularly loaded, fully rolled-up tip vortex;

0 denotes Betz roll-up from a given circulation pattern;

-1 denotes WAKE plot file entry (explained under card 0050); and

-2 denotes a nonaircraft run, appropriate for single particle release.

An entry of 3 requires a 0030 card; entry of 2 or 1 requires a 0022 card; and entry of 0 requires multiple entries of 0025 cards. The second (integer) input is the crosswind flag. A value of 0 implies no crosswind; a value of 1 implies a neutral logarithmic velocity profile, requiring a 0028 card; and a value of 2 implies a discrete velocity profile, requiring multiple entries of 0029 cards. The third entry is the semispan of the aircraft in meters (this is also the rotor radius for a helicopter, the initial y vortex coordinate for mean velocity flag = 2 and twice the initial y coordinate for mean velocity flag = 1). The fourth entry is the nominal height of the aircraft wing above the surface in meters (this distance becomes the release height for single particle release, and is the assumed nominal release height for multiple particles). For fully rolled-up tip vortices, this height is the initial z coordinate of the vortex centerline. For Betz roll-up data this height is the z coordinate of the initial vortex sheet (assumed horizontal).

The fifth entry is the flight speed of the aircraft in m/sec. The sixth entry is the biplane configuration flag (integer) and is 0 for a single wing airplane and 1 for a biplane (with further information supplied on a 0021 card). Card 0020 is a required input card.

Card 0021 requires entry on card 0020, and specifies the biplane characteristics with three entries. The first is the vertical distance in meters from the main wing location specified on card 0020 to the biplane wing. The second entry is the semispan of the biplane wing entered as a fraction of the semispan of the main wing (if the wings were equal in length this entry would be 1.0). The third entry is the vortex strength of the biplane wing entered as a fraction of the vortex strength of the main wing (for equal strengths this entry would be 1.0).

Card 0022 requires entry on card 0020, and specifies the rectangular or triangular loading circulation value, m^2/sec, for a fully rolled-up tip vortex.

Card 0025 requires entry on card 0020, and enters the Betz wing load distribution. Each card consists of two entries. The first entry is the position in meters measured from the wing root monotonically towards the tip, while the second entry gives the corresponding circulation value in m^2/sec at this location. The final card is signaled by entering the last position as the negative of its actual value. This card then forces initialization of the Betz roll-up procedure. This initialization (and the ensuing roll-up) invoke extra printer output summarizing the roll-up process. One extra, rather specific error message will be invoked if the input load distribution is not "smooth" in a sense determined by the code. In this case the error NONDISCRETE DISTRIBUTION LOCATION is displayed, suggesting that the user inspect the generated circulation derivatives for lack of monotonicity.

As the Betz roll-up continues, the particles being tracked will be

influenced by ever-increasing strength vortices, whose positions and strengths will approach those of fully rolled-up vortices. The AGDISP code includes the effect of the unrolled-up sheets on the motion of the particles.

Card 0028 requires entry on card 0020, and is the crosswind card entering the three data values needed to establish the neutral crosswind velocity profile shape. The crosswind velocity is the horizontal velocity in the y direction. The first entry is the mean wind velocity in m/sec at the altitude given by the second entry, in meters, while the third entry gives the surface roughness height z_o in meters.

Card 0029 requires entry on card 0020, and enters the discrete crosswind velocity profile. Each card consists of two entries. The first entry is the z position in meters beginning at the surface and increasing monotonically to the top of the computational domain. The second entry is the crosswind velocity value in m/sec. The final card is signaled by entering the last z position as the negative of its actual value. This card entry then initializes the turbulence level throughout the velocity profile. If a canopy is present, it is assumed that the entries on card 0029 have been modified by the user of AGDISP to reflect the influence of the canopy on the crosswind velocity profile and the subsequent turbulence calculation.

Card 0030 requires entry on card 0020, and is the helicopter card consisting of two entries. The first is the weight of the helicopter in N and the second is the blade rotation rate in rpm. The helicopter flow field is idealized as a dynamic transition from a rotor downwash field to a rectangularly loaded, fully rolled-up vortex pair.

Card 0040 is the propeller data card consisting of six entries. The first is the drag coefficient of the airplane, while the second is the planform area of the airplane in m^2. The third entry is the aircraft propeller efficiency and the fourth is the shaft rpm. The fifth is the propeller blade radius in meters and the sixth entry is the incremental distance in meters of the shaft centerline above or below the nominal release height given on card 0020 (the propeller is assumed to be at the airplane centerline, $y = 0$).

Card 0050 is the turbulence data card containing three entries. The first is an integer flag carrying one of the following values:

-1 invokes superequilibrium turbulence;

0 assumes a fixed value of turbulence given on this card; and

1,2,3 specifies the turbulent components in the attached WAKE plot file (invoked with a -1 entry on card 0020).

The other two entries on this card are the maximum value of the background turbulence q^2 in m^2/sec^2 (this value is incremented

by the presence of a crosswind), and the maximum value of the background turbulent macroscale Λ in meters. The turbulence level generated by a crosswind flowfield is equal to 0.845 $[U/\ln(z_h/z_o)]^2$ from Ref. 3, where U, z_h, and z_o are the three entries on card 0028. In most cases, this level will be sufficient to represent the ambient turbulence level (the input on card 0050 would then be 0.0 for q^2). However, in some cases, it may be necessary to augment this value for specific local atmospheric conditions. A short guide to the selection of appropriate background turbulence levels is offered in Appendix D.

The macroscale is assumed to be zero at the surface and to grow linearly with height up to the maximum value specified. If the inputted maximum value of Λ is sufficiently large, the macroscale will be proportional to z (the proportionality factor is 0.65) for all particle height positions. Card 0050 is a required input card.

Depending on the value of the integer flag, the AGDISP code may not use either of the other entries on this card (they must still be present, of course, even if they are set to 0.0). The integer entry on card 0050 defines the turbulent background characteristics and how AGDISP computes them. The determination of the background turbulence should not be confused with the use of a WAKE plot file (a -1 entry on card 0020). The presence of a WAKE plot file implies that the background horizontal and vertical velocity components are always found in the WAKE plot file. The integer entry on card 0050 defines whether additional background components are also present on the WAKE plot file. If a WAKE plot file is not invoked (the entry on card 0020 is something other than -1), only the -1 and 0 entries on card 0050 are admissible. The -1 entry on this card invokes the superequilibrium option, overriding the maximum value of q^2 entered on this card but using the maximum value of Λ . A 0 entry on card 0050 uses both maximum values of q^2 and Λ . When a WAKE plot file is present, the -1 entry again invokes the superequilibrium option and overrides the maximum value of q^2 ; the 0 entry uses both maximum values (in these instances, of course, the horizontal and vertical background velocities are recovered from the WAKE plot file), Entries of 1, 2 or 3 are valid only when a WAKE plot file exists. The 1 entry assumes that the WAKE plot file contains not only the horizontal and vertical background velocities but also the background turbulence q^2 . In this case, the maximum value entry for q^2 on card 0050 is overridden but the macroscale maximum value is used. For entries of 2 or 3 the macroscale is expected to be on the WAKE plot file, and neither of the maximum values on card 0050 is used.

The invoking of the superequilibrium option forces the spatial solution of the superequilibrium equations using an iterative solution of a linear equation solver to determine the algebraic solution to a set of nonlinear equations. Two specific errors may arise: LINEAR SOLVER ERROR IN SUPEREQUILIBRIUM and ROOT FINDER ERROR IN SUPEREQUILIBRIUM. Either error is serious, and any code results obtained after generation of the error are suspect.

A -1 entry on card 0020 invokes the WAKE plot file and forces extra output to the printer. Consistency of WAKE plot file contents and AGDISP input data is checked, with errors invoking WAKE PLOT FILE VARIABLE ERROR. The WAKE plot file configuration must be one of the following:

1. If the turbulence is superequilibrium (the turbulence flag is -1), the plot file variable list must consist of the cross-plane velocities V and W (two variables); the turbulence components are determined from superequilibrium, and the macroscale is computed algebraically using the data on card 0050.

2. If the turbulence is fixed at a specified value (the turbulence flag is 0), the turbulent components are assumed isotropic, the macroscale is computed algebraically, and the plot file variable list must contain only V and W (two variables).

3. If the turbulence flag is 1, the WAKE plot file must additionally contain q^2 (three variables), with the turbulent components assumed isotropic and the macroscale computed algebraically.

4. If the turbulence flag is 2, the WAKE plot file must additionally contain q^2 and Λ (four variables), with the turbulent components assumed isotropic.

5. If the turbulence flag is 3, the WAKE plot file contains all of the data needed to specify the mean velocity and turbulent background profiles (six variables): V , W , q^2 , Λ , $\langle vv \rangle$ and $\langle ww \rangle$.

The first nineteen words of the sequential binary WAKE plot file are a comment header field. The next integer entry gives the number of variables stored in the WAKE plot file (2, 3, 4 or 6 as explained above). This number must be consistent with what AGDISP expects. Following this integer is an identification field of length equal to the number of variables. The next integer on the WAKE plot file is the number of y (or horizontal) mesh points in the plot file, followed by these mesh values in meters. The next integer is the number of z (or vertical) mesh points, followed by these mesh values, again in meters. The code restricts these entries to 16 or less. Larger values invoke WAKE PLOT FILE MESH OUT OF RANGE.

The profile data follows, with each time slot repeating the same pattern. It begins with a single word which is the time saved in seconds. A negative time denotes end-of-data. The data for each variable on the file (specified in the order above) follows, by giving all of the y values of the first variable at the first z position, then all of the y values of the first variable at the second z position, on to the last z position; then on to all of the y values of the second variable at the first z

position, etc., until the values of all of the variables at all of the y and z positions have been given. The next time value follows, repeated to the end of the plot file. Velocities are in m/sec, scales in meters, and turbulence in m^2/sec^2. The warning message WAKE PLOT FILE EXTRAPOLATION is output the first time spatial extrapolation must be used by the AGDISP code during interpolation for the variables contained on the WAKE plot file. For times beyond the entries in the WAKE plot file, the spatial profiles nearest in time to the time being solved in AGDISP will be used.

Before integrating the particle equations, AGDISP reads the entire WAKE plot file through to the negative end-of-data. If the file is constructed incorrectly, the error message PREMATURE END OF WAKE PLOT FILE REACHED is invoked, and AGDISP terminates.

Card 0055 enters the canopy plant area profile; each card consists of two entries. The first entry is the z position in meters beginning at the surface and increasing monotonically to the top of the canopy. The second entry is the value of the plant area density (m^2/m^3) corresponding to the z location. The final card 0055 is signaled by entering the last z position as the negative of its actual value. This card entry then initializes the canopy calculation, computing the displacement thickness of the canopy and forcing modification to the crosswind velocity and turbulence within the canopy. During the AGDISP run, the trajectories of the aircraft vortices will be altered upon entering the canopy, and the position of the helicopter dividing streamline will be changed.

Card 0060 is the particle data card, containing six entries. The first entry is the integer number of particles to be followed in the half-plane ($y > 0$) ; the second entry (integer) is equal to 1 if a particle is to be released at the centerline of the aircraft ($y = 0$) ; otherwise it is equal to 0. Thus, a half-plane solution will track total particles equal to the sum of these two integers; a full-plane solution will track total particles equal to the sum of twice the first integer plus the second integer. Additionally, if these two integers are entered positive, AGDISP will position the particles uniformly along the wing (for a first integer entry of 1, the particle will be positioned at 1/2 the semispan; for a first integer entry of 2, the particles will be positioned at 1/3 and 2/3 the semispan, etc.). If these two integers are entered negative, AGDISP will expect sufficient 0061 cards in the input deck to initialize all of the particles. For both integers equal to zero, AGDISP assumes a single particle release at the centerline position.

The third entry is the vertical position in meters off-setting the particle release point from the height of the wing given on card 0020. The fourth entry is the diameter in microns of the released particles (only one particle size can be released during any one run of AGDISP). The fifth entry is the specific gravity of the released particle. The sixth entry is the (integer) evaporation flag, set to 0 for no evaporation, 1 when evaporation is invoked

and particles are retained in the computation after they evaporate to the cutoff diameter, or 2 when evaporation is invoked and particles are discarded in the computation after they evaporate to the cutoff diameter. Evaporation requires the entry of card 0065. Card 0060 is a required input card.

Card 0061 requires entry on card 0060, and is the discrete particle location entry card. There must be enough 0061 cards to satisfy the requirements of the 0060 card. If a full-plane solution is invoked <u>all</u> particle locations must be specified. If a particle is released along the centerline, that particle must be the <u>last</u> card 0061 for purposes of computing the ground deposition correctly. Each card contains two entries. The first entry is the y value in meters along the wing, while the second entry is the vertical position in meters off-setting the particle release point from the height of the wing given on card 0020. The vertical position off-set on card 0060 is disregarded. Discrete particle locations allow for fine tuning of nozzle locations, and are necessary if nozzles are not uniformly distributed along the wing or if the spray boom is not parallel to the surface.

Card 0062 is the particle initial condition data card, and consists of four entries: the initial horizontal velocity in m/sec; the initial vertical velocity in m/sec; the initial spatial variance of the particle path in m^2; and the initial velocity variance of the particle in m^2/sec^2. This card is optional; all initial conditions are set to zero unless modified by card 0062.

Card 0065 requires entry on card 0060, and is the evaporation data card, consisting of two entries; the wet bulb temperature difference in deg.C, and the particle diameter in microns, below which the user considers evaporation to have ceased. This latter number is important because the smaller the particle becomes, the smaller the step size must be to maintain numerical accuracy in solving the particle equations.

Card 0070 is the deposition height data card, and consists of one entry, the apparent height above the surface (in meters) at which the particles deposit. This card is optional, with the default condition requiring impact of the particles at the surface (with an apparent height equal to zero). For a nonzero entry, when a particle intersects the apparent deposition height, it is removed from the computation, just as though it had impacted the surface. A subsequent ground deposition plot with AGPLOT will recover the deposition of the particles at the apparent height entered on this card.

This completes the input to the AGDISP code. The calculation is performed, with periodic output to the printer of the particle positions, variances, and turbulent correlations. When a particle intersects the surface, it is no longer computed, and, therefore, its location is no longer printed. At the end of the run, the surface impact statistics are summarized and the deposition fraction (the mass fraction of particles released that have reached the ground in the desired simulation time) is computed.

4. AGPLOT INPUTS

The AGPLOT program may be invoked to plot the resulting trajectories and deposition pattern. The code asks questions of the user in the interactive environment, and with this information processes the data and plots the results. Again, entry is in free format. The plot file (constructed by an AGDISP run) is attached to unit 8, interactive output is written to the terminal on unit 6, and plots are constructed on a temporary data file using the Fort Collins DISSPLA plotting package. The plots themselves are drawn on the Tektronix screen from the temporary data file by invoking the DISSPLA driver after exiting AGPLOT.

At the beginning of AGPLOT, the data file attached to unit 8 is read, the input data deck used to generate the file is written to the screen (to serve as verification of the proper run to plot), and the file is scanned for maximum values and available options. With this information in hand, AGPLOT will display its current menu driver:

0 EXIT AGPLOT
1 MEAN PARTICLE TRAJECTORIES
2 MEAN + STANDARD DEVIATION TRAJECTORIES
3 VORTICES/HELICOPTER/PROPELLER CENTROIDS
4 GROUND DEPOSITION -- CURRENT FILE
5 GROUND DEPOSITION -- MULTIPLE FILES
6 EQUIVALENT GAUSSIAN DISTRIBUTION
7 CROSSWIND VELOCITY PROFILE
8 PLANT AREA DENSITY PROFILE
9 DROPLET DIAMETER TIME HISTORY

followed by the request ENTER OPTION TO RUN. Each of the options are described as follows:

0 is entered to exit from AGPLOT. Since postprocessing is handled by DISSPLA, several menu options may be invoked for one AGDISP run before seeing the actual plots on the Tektronix screen. Thus, 0 is the entry used to complete the plotting for a particular plot file.

1 is entered to plot the mean particle trajectories.

2 is entered to plot the mean particle trajectories (as solid curves) and the standard deviation of the particle trajectories (as dashed curves).

3 is entered to plot the trajectories of the vortex centroids (as solid curves) and the center of the propeller or the helicopter (as a dashed curve), if applicable. This option is available only with an appropriate nonzero entry on card 0011; otherwise the message OPTION NOT AVAILABLE FOR THIS FILE will appear.

4 is entered to compute and plot the ground deposition pattern for the current plot file on unit 8. The deposition pattern will be computed using Gaussian distributions whose magnitudes are

consistent with the size of the particles on impact, whose center locations correspond to the y position of the mean as the particles impact the surface, and whose standard deviations are equal to the standard deviations of the particles just before impact. If none of the particles impact the surface, the message OPTION NOT AVAILABLE FOR THIS FILE will appear. The integral under the deposition curve equals the mass fraction of deposited material. Three different deposition scales are available in AGPLOT. These scales require the mass flow rate per nozzle, and so AGPLOT requests ENTER GALLONS/MINUTE/NOZZLE to properly compute the deposition. These three scales are: NORMALIZED, LITERS/HECTARE, and DROPS/CM**2. AGPLOT requests ENTER SCALE TO USE. An integral under the deposition curve will reflect the number and mass of particles that have impacted the surface.

5 is entered to compute and plot the composite ground deposition pattern for the current plot file on unit 8 and for additional plot files (up to a total of 16 plot files) established by the user and accessed with unit numbers of 11 and higher. Because of the complexity in deciding whether two or more plot files are compatible, it was decided to forgo programming input data comparison and leave file compatibility decisions to the user. In addition the user must decide the appropriate mass fractions for each of the runs to be combined. Since the current plot file (on unit 8) is already in place, AGPLOT will request ENTER CURRENT FILE MASS FRACTION. After this AGPLOT will open unit 11 and request ENTER MASS FRACTION for the next plot file. Further plot files will be expected on units 12, 13, 14, etc. A total mass fraction of unity will terminate the requests. If the total mass fraction is not close to unity, the warning message TOTAL MASS FRACTION IS NOT 1.0 will appear. AGPLOT will represent all of the impacted particles as Gaussian distributions, as with option 4, and will respond with NO GROUND DEPOSITION FOR MULTIPLE FILES if there is none. A legend plot follows the deposition plot to identify the particle sizes and mass fractions plotted. Once option 5 has been invoked in any AGPLOT run, options 4 and 5 may not be re-invoked. The correspondence between unit numbers and file names are made with the @USE command prior to entering AGPLOT (see Appendix C for details).

6 is entered to compute and display the equivalent Gaussian distribution of the multiple-particle solution. Since the position and standard deviation of every particle in the simulation is computed by AGDISP as a function of time after particle release, the equivalent mean position and standard deviation may be determined by appropriate summation and integration at each time over all particles in the simulation. A measure of the compatibility of the equivalent Gaussian distribution is made by computing a figure of merit ranging from 0 to 1. When the equivalent Gaussian no where represents the multiple-particle distribution, the figure of merit equals zero. When the equivalent Gaussian is every where identical to the multiple distribution, the figure of merit is unity. Equivalent Gaussian calculations are made for every time on the plot file,

with all times given a monotonically increasing sequence number. The critical sequence numbers, the time associated with each of them, and their respective figure of merit are typed to the screen whenever: the first sequence number is reached; the last sequence number is reached; the figure of merit reaches a local minimum; the figure of merit reaches a local maximum; or a particle first comes within a standard deviation of the ground. After processing the entire plot file and displaying the above summary information, AGPLOT requests ENTER DESIRED SEQUENCE NUMBER to select the sequence position in the plot file at which to display the equivalent Gaussian. If a specific figure of merit is desired, the appropriate response is 0, in which case AGPLOT will request ENTER DESIRED FIGURE OF MERIT to cause the code to seek the first occurrence of the entered figure of merit. If the entered value cannot be found, the error message DESIRED FIGURE OF MERIT NOT FOUND will be invoked. Otherwise the search will be successful and the equivalent Gaussian data will be written to the screen. If the equivalent Gaussian vertical standard deviation contacts the surface, the warning message GROUND ENCOUNTER BY EQUIVALENT GAUSSIAN will be displayed on the screen. The resulting plot represents each particle distribution as dashed curves and the single equivalent Gaussian distribution as solid curves. Around each center point, normalized contour lines are plotted at one-fourth and one times the standard deviation.

7 is entered to plot the crosswind velocity profile (if available with a 0028 card or 0029 cards).

8 is entered to plot the plant area density profile (if available with 0055 cards).

9 is entered to plot the time history of a droplet diameter (only if evaporation is occurring). If there is more than one particle in the simulation, AGPLOT will request ENTER PARTICLE TO PROCESS.

Where appropriate, the following additional requests will be made:

FULL PLANE PLOT is asked whenever the AGDISP run is a half-plane run. Response in Y or N for yes or no, respectively.

AUTOSCALE AXES will compute appropriate plotting scales if invoked. If N is the response, AGPLOT will ask for Y SCALE MIN, MAX, DELTA and Z SCALE MIN, MAX, DELTA. AGPLOT has a scale checking routine and will invoke a warning message whenever the scale delta is not an integer fraction of the overall scale size. Additionally, three errors will be trapped: MAX SCALE LESS THAN MIN SCALE; SCALE DELTA LESS THAN ZERO; and TOO MANY SCALE DIVISIONS whenever more than ten scale divisions are needed.

TAG LOCATION AT TIME INCREMENTS is asked for mean particle trajectories, to tag particle positions on the plot as a function of time. The size of the tag is scaled to the size of the particle standard deviation. If the response is Y, AGPLOT will ask ENTER TAG TIME INCREMENT to enter the incremental seconds between tags.

ENTER PLOT TITLE is asked to enter the subtitle of the current plot. The main title is taken from the applicable menu option.

The completed plots are drawn to the screen by invoking DISSPLA.

5. REFERENCES

1. Teske, M. E.: "Computer Program for Prediction of the Deposition of Material Released From Fixed and Rotary Wind Aircraft." NASA CR 3780, March 1984.

2. Wachspress, D. A. and Teske, M. E.: "Running the Forest Service Dispersal Code AGDISP on the Fort Collins Computer." Continuum Dynamics, Inc., Technical Memo 84-1, February 1984.

3. Bilanin, A. J. and Teske, M. E.: "Numerical Studies of the Deposition of Materials from Fixed and Rotary Wing Aircraft." NASA CR 3779, March 1984.

4 Bliss, D. B., et. al.: "A New Methodology for Free Wake Analysis Using Curved Vortex Elements." Continuum Dynamics, Inc., Report 84-6, May 1984.

5. Bilanin, A. J. and Donaldson, C. duP.: "Estimation of Velocities and Roll-up in Aircraft Vortex Wakes." AIAA Journal of Aircraft, Vol. 12, No. 7, pp. 578-585, July 1975.

6. Pasquill, F. and Smith, F. B.: Atmospheric Diffusion, John Wiley and Sons, 1983, p. 336.

7. Csanady, G. T.: Turbulent Diffusion in the Environment, D. Reidel Publishing Company, pp. 70-72.

6. APPENDICES

The appendices of the User Manual Extension contain the following information:

APPENDIX A: a description of the subroutines used in AGDISP

APPENDIX B: a description of the subroutines used in AGPLOT

APPENDIX C: a summary of the use of AGDISP and AGPLOT for multiple deposition files

APPENDIX D: Atmospheric turbulence levels

APPENDIX A: AGDISP SUBROUTINES

This section of the Appendix summarizes the code comprising each subroutine in AGDISP. Figure A.1 presents a flowchart of AGDISP. Table A.1 highlights the important variables named in the subroutines.

AGDISP is the mainline program computing particle motion by a Lagrangian technique. Each data card has its own section in AGDISP where valid data entry is checked and initialization is performed. Card order is important, and is maintained by a series of error flags L20, L22, L25, etc. Free-format entry demands that all data cards contain the appropriate data, otherwise, an error will be trapped. Inadvertently reaching the end of the data deck also generates an error. All input cards generate output onto the terminal. After completing the input, any possible warning conditions are flagged before selecting the integration step size equal to one-half the particle time constant (this time step may be smaller if evaporation is included in the calculation). Also, the code has been configured to adjust the output frequency such that line printer output occurs approximately every one-tenth second of simulated time. Integration is then performed, after which the final particle ground deposition is computed, including the effects of evaporation. The generated plot file is used when plotting the trajectories and deposition with AGPLOT.

AGBZD evaluates the derivatives for the time-dependent solution of the Betz roll up methodology. The input parameters are the current values of the variables, the derivatives (to be computed in this subroutine), the starting pointer, maximum pointer, end pointer and total entry pointer of the current vortex circulation distribution. The variables are the radius of the vortex core and the circulation strength of the vortex. At $t = 0$, the radius is zero and the singularity is treated by taking the appropriate limit.

AGBZG initializes the Betz roll up procedure using the user-inputted circulation distribution stored in common block BETZ. The first section of the subroutine computes the spatial derivative of the circulation and sets a noise level of 0.5% of peak derivative value. The circulation distribution is then reexamined to locate where the slope is maximum (these become positions where vortices start rolling up) and where the slope is minimum (these become the end positions of the vortex circulation patterns). The noise level is used here to correct for slightly nonuniform data (a frequent occurrence when discrete data is entered). The circulation pointers to start, maximum and end for up to four vortices are then set (more than four vortices invoke an error exit from AGDISP). The initialization is completed by evaluating the derivatives at zero time and initializing all of the parameters pointing in the AGDISP code to vortex center location, strength, canopy effect and unrolled sheet effect. The code then establishes a vortex-dependent time step DTV vector based on 1% of the roll up time constant.

AGBZI integrates the Betz equations across the time step DELT entered from the AGDISP code. The first section of the subroutine establishes the time step and number of steps to integrate based on the computed values of DTV and the vortices not yet fully rolled up. Each vortex is treated separately by first predicting its new values of radius and circulation, then solving for the derivatives at these values and correcting the solution twice. The centroid of the vortex is computed based upon how much circulation has rolled into the vortex at each time step. The incremental movement of the vortex for each Betz time step is added to the current position of the vortex (this position may be influenced by the other background features incorporated in AGDISP), and fully rolled-up vortices are flagged with zero sheet strength. Lastly, the unrolled sheet lengths are determined.

AGBZQ is a Gauss-Legendre integration routine used to find the area under the inputted discrete function between inputted starting and ending points.

AGBZT is a linear interpolator extracting the value of the inputted discrete function at the inputted position.

AGCOR evaluates the particle-turbulence correlations at time T , with particle time constant DTAU and turbulence time constant WTAU . The equations are a result of the assumption of a von Karman spectral distribution as described in Ref. 3. The constants XK1, XK2, and XK3 take their limiting values whenever the two time constants are within 0.5% of each other. The correlations <ux> and <uv> are then evaluated, and these become both <uy>, <uz> and <uv>, <uw> respectively.

AGCRS computes the local value of turbulent energy associated with the discrete crosswind velocity profile shape entered with 0029 cards. A three-point, nonuniform derivative is invoked to compute the velocity gradient. Locally neutral superequilibrium is assumed to compute the QV profile.

AGDEC computes the decay rate based on the particle time constant DTAU , with evaporation causing a reduction of the time constant consistent with the smaller size particle. When the particle size reaches the termination size, evaporation is shut off. The decay rate is the sum of two terms, because of the simple evaporation model of Trayford and Welch built into the code. The drag law of Langmuir and Blodgett is used.

AGDIF evaluates the derivatives of the Lagrangian particle equations discussed in detail in Ref. 3. The time constant is evaluated, and the equations for each particle in the simulation are determined. The first and sixth elements of the vector XV are the particle positions (y,z) . At this point in space the mean velocity components V and W are determined, the background turbulent time constant is found, and the analytic particle turbulence correlations are computed. The equation derivatives are formed, with gravity equal to 9.8 m/sec^2.

AGINT monitors the integration of the particle equations. Initially, all particle positions are stored and initial derivatives determined. Integration then proceeds step by step to the maximum inputted time. The WAKE plot file, Betz, canopy, propeller and helicopter are updated where applicable, particle positions are predicted, derivatives evaluated, and the positions are twice corrected. Particle solutions terminate at the deposition height. Since the vortices move under the influence of one another and their ground images, their positions are also adjusted. Any particles that have impacted the surface are flagged and their final sizes are computed. Termination is checked for evaporation, maximum time, and ground impact; and plot save is invoked. If termination exists, transfer is returned to AGDISP; otherwise another time step is taken.

AGLQD is a linear decomposition routine used to decompose the six-by-six matrix in the superequilibrium methodology.

AGLQS is the linear substitution routine used to evaluate the six superequilibrium unknowns.

AGMAT fills the six-by-six matrix array for the unknowns $\langle uu \rangle$, $\langle vv \rangle$, $\langle ww \rangle$, $\langle uv \rangle$, $\langle uw \rangle$ and $\langle vw \rangle$ by superequilibrium for a given value of q^2. The linear equations are solved by AGLQD and AGLQS to determine the difference between q^2 and $\langle uu \rangle + \langle vv \rangle + \langle ww \rangle$.

AGPAC computes the vortex circulation reduction resulting from interactions with a canopy. Essentially, the scrubbing of the vortex acts as a drag on the wake flow field. The drag translates into an effective vortex strength smaller than the noncanopy value. In this subroutine vortices are checked for whether they have penetrated the canopy; if so, an integration across the portion of the vortex interacting with the plant area density is taken, a simple time integration is performed, and the vortex strength reduction factor is computed. The reduction factors FACR and FACL modify the vortex strengths, unrolled sheet strengths, propeller swirl and helicopter effects.

AGPAD computes the displacement thickness of the plant canopy and initializes the effective circulation integrals. The displacement thickness is assumed to represent the effective surface roughness the canopy gives the atmospheric flow above it. Within the canopy, the crosswind velocity and turbulence are assumed to behave linearly with height.

AGRTF is a root-finder routine that performs higher-order interpolation to yield a solution for q^2 which agrees accurately with $\langle uu \rangle + \langle vv \rangle + \langle ww \rangle$ obtained by solving the six-by-six matrix set. The solution speed is enhanced by starting the iteration at a value of q^2 close to the answer.

AGSAV writes the step integration results from AGDISP to the plot file (mean particle position and standard deviation) and the line printer (all variables for all nonimpacted particles). With the proper flags set, this routine will also plot and print vortex center locations, and propeller and helicopter midpoints.

AGSUP is the driving routine for superequilibrium. Given the four spatial derivatives in the AGDISP code (dU/dy and dU/dz are zero) and the local scale length, the superequilibrium equations are iterated for the values of $\langle uu \rangle$, $\langle vv \rangle$ and $\langle ww \rangle$. The maximum gradient is used to normalize the solver, an approximate result is selected, and then an accurate solution is found by stepping in q until a zero crossing is found by invoking the root finder AGRTF to obtain a value of q accurate to four digits or a normalized value of $q^2 - \langle uu \rangle - \langle vv \rangle - \langle ww \rangle$ within $\pm$ 0.001 m^2/sec^2 of zero. This result produces the values of turbulent energy unnormalized by scale length and the normalizing velocity gradient. Any (rare) error trap returns laminar results in an effort to reduce the impact of the background solution on the particle equations.

AGSVE computes the incremental background velocity arising from the unrolled Betz sheets. In this case, the sheets are represented by a constant circulation sheet of vorticity, and the resulting flow is analytically determined. The singularity in the vicinity of the sheet is controlled by keeping all data evaluation at a distance of 1% of the sheet length with linear fall-off within 10%. As the Betz procedure continues, the sheet becomes shorter until it is finally rolled up.

AGTUR determines the turbulence scale length and turbulent components q^2, $\langle vv \rangle$ and $\langle ww \rangle$ at the position (y,z). The scale is essentially the smaller of 0.65z, the maximum inputted scale, or six-tenths the distance to the nearest vortex. The turbulence comes from superequilibrium or the fixed inputted value (modified by the propeller wake). The values will be modified if the particle position is within the canopy (a linear correction to the height of the canopy). Alternately, the scale and correlations could in all or part come from a WAKE plot file.

AGVCH examines each vortex location and propeller and helicopter centerline and corrects for their movement in the given time step DELT.

AGVEL computes the mean velocity components V and W at the position (y,z). Each vortex, its reflecting image across $y = 0$ and their images across $z = 0$ are used to compute the overall velocity increment. The standard potential vortex velocity field producing a velocity normal to the radius vector is broken into its (y,z) components and modified by FACR and FACL for the presence of a canopy. The unrolled sheet effect (with image sheets) is added, as are the helicopter, propeller and mean crosswind modified by the canopy. Alternately, the WAKE plot file is quizzed to return the appropriate velocity components.

AGWKI linearly interpolates the data array read from the WAKE plot file for the variable desired (V, W, q^2, scale length, $\langle vv \rangle$ or $\langle ww \rangle$) at the position (y,z). A warning message is written the first time spatial extrapolation beyond the WAKE plot file grid coordinate is invoked, even though extrapolation may continue indefinitely thereafter.

AGWKR recovers the WAKE plot file data for the desired time T . Interpolation between time steps is performed every one-tenth of the interval; otherwise the data arrays in common block WAKE are not updated. The file is rewound, the initial data skipped, and the pertinent time step bracketed. Linear interpolation is then performed, and the next time check is computed. When the end of the WAKE plot file is reached, the last time entry data is used for the duration of the AGDISP run.

AGWKS processes the WAKE plot file header information. The file is binary and is read sequentially. The plot file comment of nineteen words is followed by the number of variables, a list of the variable names, the number of y data points, the values of the y mesh , the number of z data points and the values of the z mesh. Thereafter, the data consists of a time entry followed by all y data values for each z mesh row for each variable.

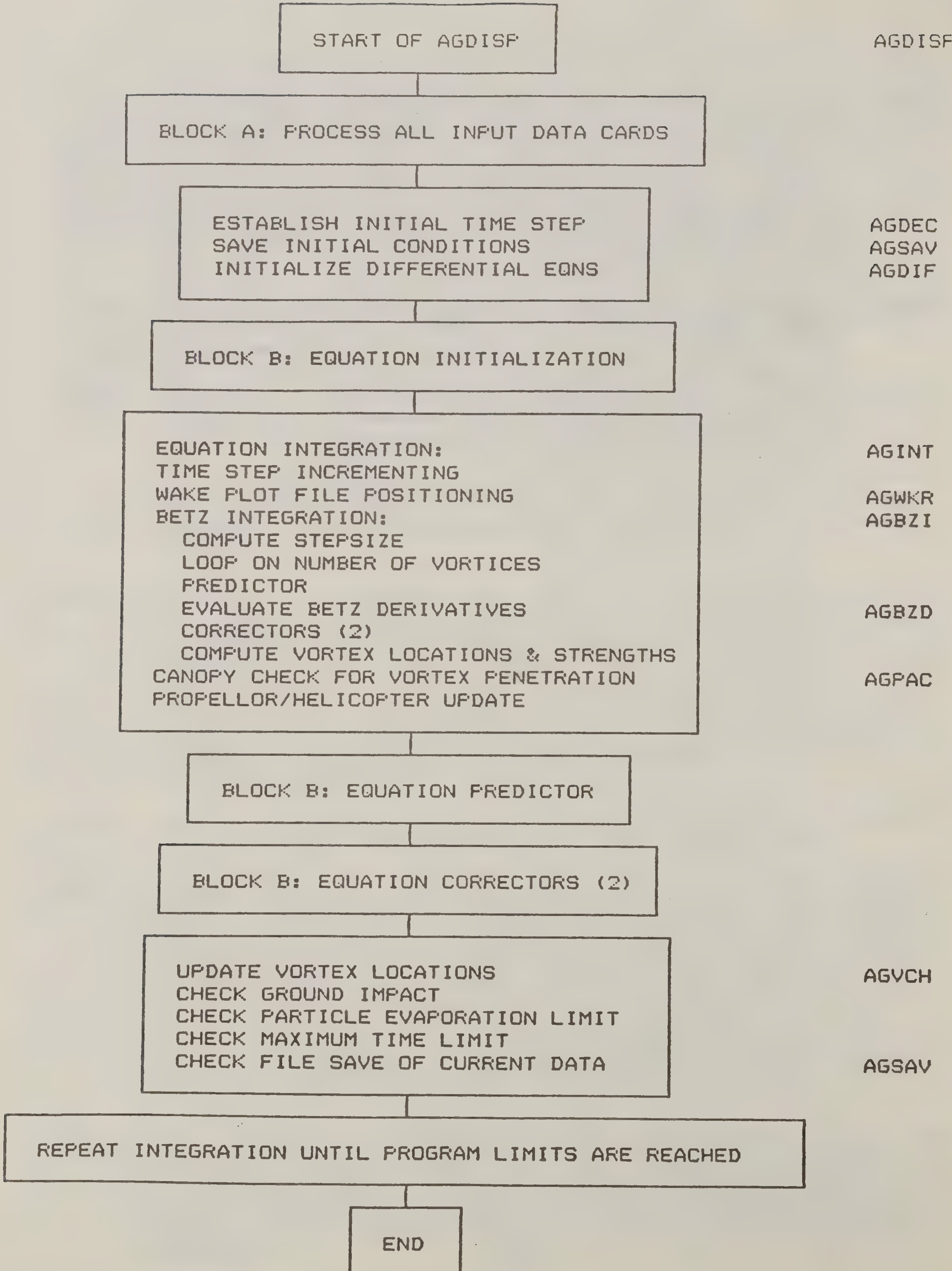


Figure A.1: ACDISP flow chart

BLOCK A: INPUT DATA CARDS

0000 COMMENT CARD
0010 PROGRAM CONTROL CARD
0011 PRINTER/PLOTTER CONTROL CARD
0015 TERRAIN SLOPE CARD
0020 AIRCRAFT CHARACTERISTICS CARD
0021 BIPLANE CHARACTERISTICS CARD
0022 AIRPLANE WING LOADING CARD
0025 BETZ ROLLUP CARDS
BETZ INITIALIZER:
EVALUATE LOAD DISTRIBUTION AGBZG
INITIALIZE TIME-DEPENDENT EQNS AGBZD
GAUSS-LEGENDRE QUADRATURE AGBZQ
TABLE INTERPOLATOR AGBZT
0028 NEUTRAL CROSSWIND DATA CARD
0029 DISCRETE CROSSWIND DATA CARDS AGCRS
0030 HELICOPTER CARD
0040 PROPELLER CARD
0050 TURBULENCE CARD
WAKE PLOT FILE INITIALIZER:
EXTRACT INITIAL DATA ON FILE AGWKS
DETERMINE INITIAL SPATIAL DATA AGWKR
0055 CANOPY CARDS
CANOPY INITIALIZER:
COMPUTE CANOPY HEIGHT &
EFFECTIVE ROUGHNESS AGPAD
0060 PARTICLE CARD
0061 DISCRETE PARTICLE LOCATION CARDS
0062 PARTICLE INITIAL CONDITION CARD
0065 EVAPORATION CARD
0070 DEPOSITION HEIGHT CARD

REPEAT UNTIL INPUT IS COMPLETE

RETURN

Figure A.1: continued

BLOCK B: DIFFERENTIAL EQNS

EVALUATE EQUATION DERIVATIVES — AGDIF

EVALUATE PARTICLE TIME CONSTANT — AGDEC

DETERMINE LOCAL VELOCITY DUE TO: — AGVEL
VORTICES
BETZ UNROLLED UP SHEETS — AGSVE
CROSSWIND
PROPELLER/HELICOPTER
WAKE PLOT FILE INTERPOLATION — AGWKI

DETERMINE TURBULENCE AND SCALE FROM: — AGTUR
FIXED INPUT VALUES
WAKE PLOT FILE INTERPOLATION — AGWKI
CANOPY
PROPELLER/HELICOPTER
SUPEREQUILIBRIUM: — AGSUP
ROOT FINDER ITERATION FOR CONSISTANT qq — AGRTF
COMPUTE TURBULENT COMPONENTS IN 6X6 MATRIX — AGMAT
LINEAR DECOMPOSITION — AGLQD
LINEAR SUBSTITUTION — AGLQS

COMPUTE ATMOSPHERIC CORRELATIONS — AGCOR

EVALUATE DERIVATIVES FOR:
1 y POSITION
2 v VELOCITY
3 <yy> VARIANCE
4 <uv> CORRELATION
5 <vv> VARIANCE
6 z POSITION
7 w VELOCITY
8 <zz> VARIANCE
9 <zw> CORRELATION
10 <ww> VARIANCE

RETURN

Figure A.1: continued

TABLE A.1: AGDISP variable list

NAME	SUBR	DESCRIPTION
AGV	AGBZG	vector: absolute value of Betz circulation distribution
APRP	AGDISP	initial frontal area of propeller
AS	AGDISP	airplane planform area
ASV	AGFAC	vector: integrand of average plant area density
AV	AGDISP AGFAC AGFAD	vector: inputted plant area density; function of ZV
	AGWKI AGWKR AGWKS	vector: wake plot file contents at a specified
CD	AGDISP	airplane drag coefficient
	AGFAC	effective plant canopy vortex drag coefficient
CHF	AGDISP AGINT	helicopter transition factor (hover to vortices)
CHG	AGDISP AGINT	helicopter circulation factor (vortices)
CHW	AGDISP AGINT	helicopter downwash factor (hover)
CHZ	AGDISP AGINT	helicopter apparent surface height
CPQ	AGDISP AGINT	propeller turbulence factor
CPR	AGDISP AGINT	propeller radius factor
CTA	AGDISP	cosine of terrain angle
CV	AGDISP	comment vector
DCUT	AGDEC AGDISP	particle diameter below which evaporation ceases
DECAY	AGDIF	particle decay constant
DELT	AGBZI AGFAC AGVCH	integration time step
DENF	AGDEC AGDISP	particle specific gravity
DGMM	AGBZG	error tolerance on computed Betz circulation

TABLE A.1 (continued)

NAME	SUBR	DESCRIPTION
DGV	AGBZD AGBZG AGBZI	vector: Betz circulation derivs: functions of YV
DIAM	AGDEC AGDISP	particle diameter
DIST	AGBZG AGDISP	initial vertical distance from ground to Betz vortex shee initial vertical distance from ground to tip vo
DMCV	AGDISP AGINT	vector: particle volume ratio at surface impact
DNV	AGBZI AGINT	vector: new time derivs of Betz vortex eqns vector: new time derivs of particle eqns
DOV	AGBZG AGBZI AGINT	vector: old time derivs of Betz vortex eqns vector: old time derivs of particle eqns
DSYM	AGBZG AGBZI AGVEL	vector: unrolled Betz sheet length left-of-centroid
DSYP	AGBZG AGBZI AGVEL	vector: unrolled Betz sheet length right-of-centroid
DT	AGBZI AGDISP AGINT	integration time step
DTAU	AGCOR AGDEC AGDIF AGDISP	particle relaxation time
DTEMP	AGDEC AGDISP	evaporation wet bulb temperature difference
DTMN	AGDIF AGINT	minimum particle relaxation time
DTV	AGBZG AGBZI	vector: Betz integration time step for each vortex
DU	AGDEC	particle velocity relative to local mean wind velocity
DV	AGBZD AGDIF AGMAT AGSUP	vector: new time derivatives of Betz vortex eqns vector: new time derivatives of particle eqns vector: superequilibrium turbulence solution

TABLE A.1 (continued)

NAME	SUBR	DESCRIPTION
DVDY	AGSUP AGTUR	deriv of horizontal velocity wrt horizontal distance
DVDZ	AGSUP AGTUR	deriv of horizontal velocity wrt vertical distance
DWDY	AGSUP AGTUR	deriv of vertical velocity wrt horizontal distance
DWDZ	AGSUP AGTUR	deriv of vertical velocity wrt vertical distance
DY	AGBZG AGBZI	Betz fully rolled up vortex radius horizontal increment in Betz vortex location
DZ	AGBZG AGBZI AGDISP	distance above DIST to biplane vertical location vertical increment in Betz vortex location incremental vertical distance
DZBP	AGDISP	incremental vertical distance from DIST to biplane
D1	AGBZD	Betz left-of-centroid spatial circulation derivative
D2	AGBZD	Betz right-of-centroid spatial circulation derivative
EDNV	AGDEC AGINT	vector: present time step particle diameter
EDOV	AGDEC AGDISP AGINT	vector: previous time step particle diameter
EPS	AGDEC AGSUP AGTUR	particle decay constant incremental turbulence level for root finding continuity equation error
ETA	AGDISP	airplane propeller efficiency
ETAU	AGDEC	particle evaporation relaxation time
FACL	AGBZG AGDISP AGPAC AGVEL	vector: plant canopy circulation reduction -Y vortices
FACR	AGBZG AGDISP AGPAC AGVEL	vector: plant canopy circulation reduction +Y vortices
FL	AGPAC AGPAD	vector: plant area density integral -Y vortices

TABLE A.1 (continued)

NAME	SUBR	DESCRIPTION
FR	AGPAC AGPAD	vector: plant area density integral +Y vortices
G	AGSVE	Betz unrolled vortex circulation strength
GAMMA	AGDISP	triangular/rectangular vortex circulation strength
GSAV	AGBZG AGBZI AGDISP AGVEL	vector: Betz average sheet circulation per unit length
GV	AGBZG AGBZI AGDISP	vector: inputted Betz circulation; function of YV
G1	AGBZI	Betz left-of-centroid circulation value
G2	AGBZI	Betz right-of-centroid circulation value
G2PI	AGBZG AGBZI AGDISP AGPAC AGVEL	vector: circulation divided by two pi
HHEL	AGDISP AGINT AGVEL	initial height of helicopter rotor plane above surface
HTPAD	AGDISP AGINT AGPAC AGTUR AGVEL	plant canopy maximum height above surface
ICARD	AGDISP	running count of input cards
ICV	AGDISP	vector: input card numbers
IFL	AGPAC AGPAD	vector: -Y vortex within plant canopy flag
IFR	AGPAC AGPAD	vector: +Y vortex within plant canopy flag
IOUT	AGINT AGSAV	terminal output flag
ISW	AGINT AGSAV	vector: individual particle-to-ground impact flag

TABLE A.1 (continued)

NAME	SUBR	DESCRIPTION
ISWC	AGINT AGSAV	summed particle-to-ground impact flag
IY	AGWKI	horizontal vector location within wake array data
IZ	AGWKI	vertical vector location within wake array data
LBP	AGDISP	biplane flag
LCV	AGDISP	vector: admissible input card entries
LEVAP	AGDEC AGDISP AGINT	evaporation flag
LHFPL	AGDISP	half-plane/full-plane flag
LMCRS	AGDISP AGVEL	mean cross wind flag
LMVEL	AGDISP AGINT AGVCH AGVEL	mean velocity flag
LOC	AGDISP	input card counter
LOCA	AGDISP	plant area density input card counter
LOCB	AGDISP	Betz circulation input card counter
LOCC	AGDISP	crosswind input card counter
LPART	AGDISP	particle flag
LPRP	AGDISP AGINT AGTUR AGVCH AGVEL	propeller flag
LQQSE	AGDISP AGTUR	turbulence flag
LV	AGDISP AGINT	vector: input card flags vector: positive definite variables flag
LZERO	AGDISP	centerline particle flag
Lmn	AGDISP	card 00mn flag
ME	AGBZD AGBZG AGBZI	ending pointer for Betz vortex circulation

TABLE A.1 (continued)

NAME	SUBR	DESCRIPTION
MEV	AGBZG AGBZI	vector: ME values for all Betz vortices
MS	AGBZD AGBZG AGBZI	starting pointer for Betz vortex circulation
MSV	AGBZG AGBZI	vector: MS values for all Betz vortices
MT	AGBZD AGBZG AGBZI	total discrete points in Betz vortex circulation
MX	AGBZD AGBZG AGBZI	position of maximum Betz circulation derivative
MXV	AGBZG AGBZI	vector: MX values for all Betz vortices
NBTZ	AGBZG AGBZI	number of Betz vortices
NCRS	AGCRS AGDISP	number of discrete crosswind velocity data points
NDAT	AGDISP	card input file unit number
NENDF	AGWKR AGWKS	wake plot file record position counter
NEXTF	AGWKI AGWKS	wake plot file extrapolation flag
NF	AGWKR	wake plot file record read counter
NGAM	AGBZG AGDISP	number of discrete inputted Betz circulation data points
NMAX	AGWKS	maximum admissible grid positions in wake plot file
NOUT	AGBZG AGCRS AGDISP AGMAT AGPAD AGSAV AGSUP AGWKS	terminal output unit number
NPAD	AGDISP AGPAC AGPAD	number of discrete inputted plant area density data point

TABLE A.1 (continued)

NAME	SUBR	DESCRIPTION
NPLT	AGDISP AGSAV	plot output file unit number
NPRT	AGBZG AGBZI AGDISP AGPAC AGSAV AGWKI AGWKR	printer output file unit number
NPTJ	AGDISP AGSAV	frequency of trajectory plot output file writes
NPVX	AGDISP AGSAV	frequency of vortices/centerlines plot output file writes
NSAV	AGDISP AGINT AGSAV	frequency of writes to plot output file
NSTEP	AGINT AGSAV	step number counter
NV	AGWKS	vector: number of admissible variables in wake plot file
NVAR	AGDIF AGDISP AGINT AGSAV	total number of particles
NVOR	AGBZG AGBZI AGDISP AGPAC AGTUR AGVCH AGVEL	total number of vortices
NWPF	AGWKR AGWKS	wake plot file unit number
NWPV	AGWKR AGWKS	total number of wake plot file variables
NY	AGWKI AGWKR AGWKS	total number of horizontal points in wake plot file
NZ	AGWKI AGWKR AGWKS	total number of vertical points in wake plot file

TABLE A.1 (continued)

NAME	SUBR	DESCRIPTION
PGBP	AGBZG AGBZI AGDISP	biplane circulation factor
PSBP	AGBZG AGBZI AGDISP	biplane semispan factor
PV	AGCRS AGDISP	vector: inputted vertical locations of crosswind velocity
QQ	AGDIF AGTUR	local background turbulence level
QQMX	AGDISP AGTUR	constant background turbulence level
QQPRP	AGDISP AGINT AGTUR	propeller turbulence level
QV	AGCRS	vector: computed crosswind turbulence level
R	AGTUR AGVEL	radius
REYNO	AGDEC	Reynolds number based on relative velocity
RHEL	AGDISP AGINT AGVEL	helicopter blade radius
RLIM	AGBZG AGDISP AGVEL	limiting cutoff radius for triangular wing loading
RPRP	AGDISP AGINT AGTUR AGVEL	radius of propeller flow field
S	AGDISP AGSVE AGVEL	airplane semispan length of unrolled Betz vortex sheet
SL	AGDIF AGTUR	turbulent macroscale length
SLMX	AGDISP AGTUR	maximum turbulent macroscale length
SRV	AGBZG AGBZI AGDISP AGPAC	vector: vortex core radius

TABLE A.1 (continued)

NAME	SUBR	DESCRIPTION
STA	AGDISP	sine of terrain angle
T	AGCOR AGDEC AGDIF AGINT AGSAV AGWKR	integration time
TA	AGDISP	terrain slope angle
TDOT	AGDISP	propeller shaft rpm
TIME	AGBZI AGDISP	integration time
TMAX	AGDEC AGDISP AGINT	maximum integration time
TMCV	AGDISP AGINT	vector: time of particle impact with surface
TR	AGWKR AGWKS	wake plot file interpolation time
U	AGDISP	crosswind reference velocity
UO	AGDISP AGINT	aircraft flight speed
USK	AGDISP AGVEL	shear stress constant for crosswind evaluation
UU	AGSUP AGTUR	local background axial turbulence component
UV	AGCOR AGDIF	particle velocity/background velocity correlation
	AGCRS AGDISP	vector: inputted crosswind velocity
UX	AGCOR AGDIF	particle position/background velocity correlation
UY	AGMAT AGSUP	deriv of axial velocity wrt horizontal distance
UZ	AGMAT AGSUP	deriv of axial velocity wrt vertical distance
V	AGDIF AGDISP AGSVE AGVEL	horizontal velocity

TABLE A.1 (continued)

NAME	SUBR	DESCRIPTION
VPRP	AGDISP AGINT AGVEL	propeller tip speed
VV	AGDIF AGSUP AGTUR	local background horizontal turbulence component
VY	AGMAT AGSUP	deriv of horizontal velocity wrt horizontal distance
VZ	AGMAT AGSUP	deriv of horizontal velocity wrt vertical distance
W	AGDIF AGDISP AGSVE AGVEL	vertical velocity
WHEL	AGDISP AGINT AGVEL	helicopter downwash velocity at blade plane
WT	AGDISP	helicopter weight
WTAU	AGCOR AGDIF	turbulent relaxation time
WW	AGDIF AGSUP AGTUR	local background vertical turbulence component
WY	AGMAT AGSUP	deriv of vertical velocity wrt horizontal distance
WZ	AGMAT AGSUP	deriv of vertical velocity wrt vertical distance
X	AGINT AGSVE AGWKI	axial distance measured from particle release point
XMU	AGDISP	helicopter forward advance ratio
XNV	AGBZI AGINT	vector: new time values of Betz vortex eqns vector: new time values of particle eqns
XO	AGINT AGVEL	axial distance measured from particle release point
XOV	AGBZG AGBZI AGDISP AGINT	vector: old time values of Betz vortex eqns vector: old time values of particle eqns

TABLE A.1 (continued)

NAME	SUBR	DESCRIPTION
XPR	AGDISP	propeller axial virtual origin
	AGINT	
XV	AGBZD	vector: new time values of Betz vortex eqns
	AGDIF	vector: new time values of particle eqns
	AGSAV	
X1	AGBZI	Betz integral for left-of-centroid
X2	AGBZI	Betz integral for right-of-centroid
Y	AGDISP	horizontal distance
	AGSVE	
	AGTUR	
	AGVEL	
	AGWKI	
YBAL	AGBZG	vector: horizontal location of -Y vortices
	AGBZI	
	AGDISP	
	AGTUR	
	AGVCH	
	AGVEL	
YBAR	AGBZG	vector: horizontal location of +Y vortices
	AGBZI	
	AGDISP	
	AGTUR	
	AGVCH	
	AGVEL	
YE	AGBZI	right-of-centroid maximum location of Betz rollup
YHEL	AGDISP	horizontal location of helicopter centerline
	AGINT	
	AGVCH	
	AGVEL	
YNV	AGBZI	new horizontal location of Betz vortex centerline
YOV	AGBZG	vector: old horizontal location of Betz vortex centerline
	AGBZI	
YPRP	AGDISP	horizontal location of propeller centerline
	AGTUR	
	AGVCH	
	AGVEL	
YS	AGBZI	left-of-centroid minimum location of Betz rollup
YV	AGBZD	vector: inputted discrete stations for Betz circulation
	AGBZG	
	AGBZI	
	AGDISP	
	AGWKI	vector: horizontal spatial locations in wake pl
	AGWKS	

NAME	SUBR	DESCRIPTION
Y1	AGBZD AGBZI	left-of-centroid location of Betz rollup point
Y2	AGBZD AGBZI	right-of-centroid location of Betz rollup point
Z	AGDISP AGSVE AGTUR AGVEL AGWKI	vertical distance
ZBAL	AGBZG AGBZI AGDISP AGPAC AGTUR AGVCH AGVEL	vector: vertical location of -Y vortices
ZBAR	AGBZG AGBZI AGDISP AGPAC AGTUR AGVCH AGVEL	vector: vertical location of +Y vortices
ZHEL	AGDISP AGINT AGVEL	vertical location of helicopter centerline
ZNV	AGBZI	new vertical location of Betz vortex centerline
ZO	AGDISP AGVEL	surface roughness height
ZOPAD	AGDISP AGVEL	plant canopy effective surface roughness height
ZOV	AGBZG AGBZI	vector: old vertical location of Betz vortex centerlines
ZPRP	AGDISP AGTUR AGVCH AGVEL	vertical location of propeller centerline
ZREF	AGDISP AGINT	apparent surface height
ZV	AGDISP AGPAC AGPAD	vector: inputted vertical locations of plant area density
	AGWKI AGWKS	vector: vertical spatial locations in wake plot

APPENDIX B: AGPLOT SUBROUTINES

This section of the Appendix summarizes the code comprising each subroutine in AGPLOT. Figure B.1 presents a flowchart of AGPLOT. Table B.1 highlights the important variables named in the subroutine.

AGPLOT is the mainline program for plotting the results from AGDISP. The program first reads the plot file and computes minimum and maximum values, and identifies file options. The user then selects from a menu of possible plot options, including plotting mean particle trajectories, trajectories including the turbulent standard deviation, trajectories of vortices or propeller or helicopter centerlines, ground deposition, equivalent Gaussian distribution, or profiles of crosswind velocity or plant area density. Multiple plots may be constructed before invoking program exit. After the running of AGPLOT, the user must access DISSPLA to plot the information to the Tektronix screen.

AGASC computes minimum, maximum and delta scale values to include available data and presents a visually pleasing scale division. The algorithm uses a base ten power law to decide on scale divisions.

AGCHK verifies the appropriateness of the scaling information requested by AGPLOT of the user. In all cases, the scale must be monotonically increasing with a positive spacing between scale divisions and an integer number of scale divisions, not to exceed ten.

AGDRP reads the plot file to recover the time history of a specific particle diameter undergoing evaporation.

AGDRW invokes a DISSPLA routine to draw a data curve. If a plane of symmetry exists, the data is translated to the negative axis and also drawn.

AGEQD computes the equivalent Gaussian distribution of the multiple-particle solution (including the particle solution on the other half of a half-plane solution). The mean horizontal and vertical positions and standard deviations are summed over all particles in the solution plane, and the figure of merit is computed.

AGEQG interprets the plot file to construct an equivalent Gaussian profile distribution from the multiple-particle solution known at every time step. Two passes are made through the plot file. The first pass computes the equivalent Gaussian and figure of merit at every saved time in the plot file, and displays to the screen the points of maximum and minimum figure of merit, when the particles impact the surface, and when the equivalent Gaussian is within a standard deviation of the surface. From this information the user decides which time to plot, and the program locates that time in the second pass and creates the equivalent plots.

AGEQP sets up and plots the particle isopleths.

AGGRD quizzes the user for multiple plot files and computes the ground deposition pattern. Each impacting particle in the AGDISP simulation hits the surface at a known y position with a known variance. Adding all particle locations with their known impact sizes produces the deposition pattern along the surface.

AGPLT is the plotting subroutine that uses DISSPLA graphics calls to perform the actual plotting. The screen is first cleared, then axes are established and plotted and a wing schematic is drawn. The plot file is read so that nine points are plotted at a time, drawing the mean particle paths (including the image if desired), the standard deviation paths, the vortices and propeller or helicopter centerline paths, tag markers at the desired interval, array profiles, (including ground deposition), and equivalent Gaussian profiles.

AGRPF rereads the front of the plot file to recover input code data for crosswind velocity or plant area density profiles.

AGSCP sets the curve pattern for the multiple ground deposition plots and constructs the legend plot that summarizes the curves used.

AGSET completes the plotting setup by checking for a full-plane plot (with a half-plane solution), autoscaling of axes, and tag markers at specified time intervals. The plotting process is then invoked with a call to AGPLT.

AGSPD uses the stored plot file variables to determine the plotting coordinates of the particle standard deviation, normal to the instantaneous particle direction.

Graphics calls are invoked with DISSPLA subroutine calls. These calls establish a temporary disk file that contains all the necessary plotting information. Post processing after AGPLOT (by invoking DISSPLA) permits this file to be interpreted, and allows the plotting images to be placed on the Tektronix screen. The subroutines invoked during the running of AGPLOT follow.

AREA2D specifies the subplot area, the area between the axes where plotting will occur.

COMPRS forces DISSPLA to create a temporary disk file (called a "metafile" in the DISSPLA literature).

CURVE plots a two-dimensional set of data.

DASH invokes an interrupted line (dashed) pattern.

DONEPL terminates a plotting session (which can include several plots).

ENDPL ends a specific plot.

GRACE sets a margin around the subplot area beyond which plot curves are not plotted.

GRAF sets up the basic scale axes for a plot.

HEADIN defines a plot title.

HEIGHT specifies the height of the text (also adjusts scale label height).

INTNO sends an integer label to the plot.

MESSAG sends a message label to the plot.

MRSCOD specifies the pen up-down pattern for user-defined curves.

NOCHEK suppresses the listing of plotted points outside the grace margin.

PAGE sets the overall plot size (including scales, labels, and plot title).

RESET resets a parameter to its default value (in this case it "turns off" the dash line option to give solid lines).

SETEND changes the ending string termination character.

SIMPLX invokes the DISSPLA SIMPLX character font.

XNAME titles the X (horizontal) axis.

XTICKS sets the number of X axis tick marks.

YAXANG sets the angle of the Y-axis scale labels.

YNAME titles the Y (vertical) axis.

YTICKS sets the number of Y axis tick marks.

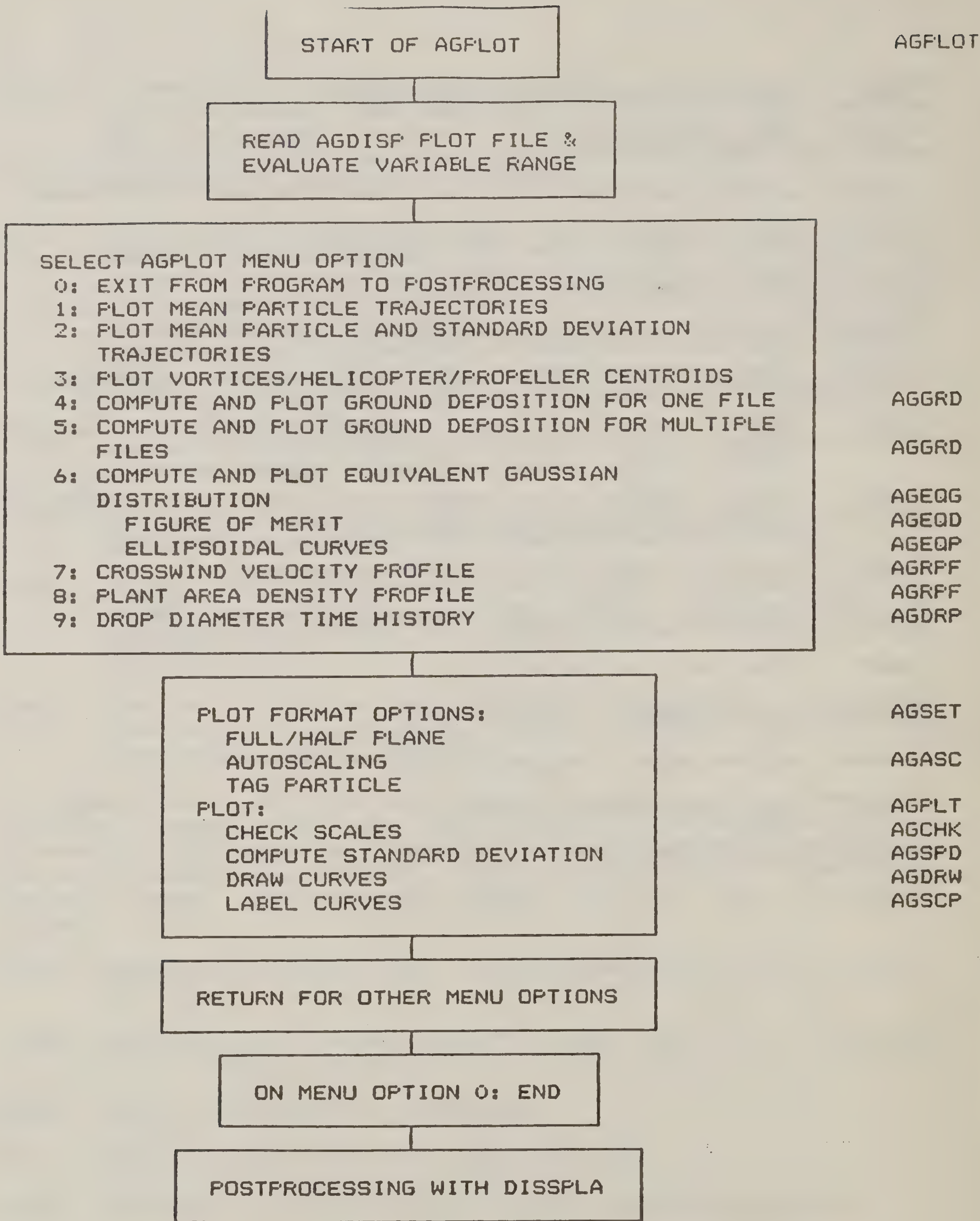


Figure B.1: AGPLOT flow chart

TABLE B.1: AGPLOT variable list

NAME	SUBR	DESCRIPTION
AV	AGPLT AGSPD	vector: particle solution from plot output file
CBAR	AGEQD	equivalent Gaussian magnitude
DCV	AGEQD AGEQG	vector: particle diameter factors
DELT	AGPLT AGSET	tag time increment
DFOM	AGEQD AGEQG	desired figure of merit
DIST	AGPLOT AGSPD	initial vertical distance from surface to aircraft wing
DMCV	AGGRD	vector: particle volume ratio in deposition files
DV	AGGRD AGPLOT	vector: horizontal spread and location at surface impact
DZBP	AGPLOT	incremental vertical distance from DIST to biplane
FOM	AGEQD AGEQG	equivalent Gaussian figure of merit
FV	AGGRD	vector: mass fraction in deposition files
ICARD	AGPLOT	running count of AGDISP input cards
ICV	AGEQG AGGRD	vector: surface impact flag
IDIR	AGEQG	minimum/maximum figure of merit flag
IGRD	AGPLOT	deposition completed flag
IOPT	AGPLOT AGPLT	current menu option number
IVAR	AGGRD	vector: number of particles in deposition files
IZERO	AGEQG	number of particles with zero spread
LAPLT	AGPLOT AGPLT AGSET	array plot flag
LEPLT	AGPLOT AGPLT AGSET	equivalent Gaussian distribution plot flag
LEVAP	AGPLOT	evaporation flag

TABLE B.1 (continued)

NAME	SUBR	DESCRIPTION
LFOLD	AGPLOT AGPLT AGSET	symmetry plot flag
LHEL	AGEQG AGPLOT AGPLT	flag for helicopter centerlines to plot
LHF	AGGRD	vector: half-plane/full-plane flag in deposition files
LHFPL	AGEQD AGPLOT AGSET	half-plane/full-plane flag
LMPLT	AGPLOT AGPLT	mean particle trajectory plot flag
LPRP	AGEQG AGPLOT AGPLT	flag for propeller centerlines to plot
LSPLT	AGPLOT AGPLT	standard deviation trajectory plot flag
LTOT	AGEQG AGPLOT AGPLT	LVOR + LHEL + LPRP
LTPLT	AGPLOT AGPLT AGSET	tag plot flag
LVOR	AGEQG AGPLOT AGPLT	flag for vortex centroids to plot
LVPLT	AGPLOT AGPLT	vortices/propeller/helicopter trajectory plot flag
LZERO	AGEQD AGPLOT	centerline particle flag
LZR	AGGRD	vector: centerline particle flag in deposition files
NINU	AGEQG AGGRD AGPLOT AGPLT AGSET	terminal input unit number
NOUT	AGCHK AGEQG AGGRD AGPLOT AGPLT	terminal output unit number

TABLE B.1 (continued)

NAME	SUBR	DESCRIPTION
NPLT	AGEQG AGPLOT AGPLT AGRPF	plot input file unit number
NPTS	AGEQG	desired sequence number
NVAR	AGEQD AGEQG AGGRD AGPLOT AGPLT	total number of particles
NVEC	AGGRD AGPLT AGRPF	number of entries in YVEC and ZVEC
PV	AGPLT	vector: propeller/helicopter centerlines from plot file
S	AGPLOT	aircraft semispan
TA	AGPLOT AGPLT	terrain slope angle
TIME	AGPLT	simulation time
TMAX	AGPLOT	maximum simulation time
VLV	AGPLT	vector: -Y vortices from plot file
VRV	AGPLT	vector: +Y vortices from plot file
XFn	AGEQD	figure of merit intervals (n=1 to 4)
YCB	AGEQD AGPLT	equivalent Gaussian horizontal position
YCV	AGEQD AGEQG AGPLT	vector: horizontal particle mean positions
YGMN	AGPLOT	minimum horizontal value for ground deposition
YGMX	AGPLOT	maximum horizontal value for ground deposition
YMAX	AGEQG AGGRD AGPLOT	horizontal axis plot scale maximum
YMIN	AGEQG AGGRD AGPLOT	horizontal axis plot scale minimum
YMMN	AGPLOT	minimum horizontal value for mean particle trajectories

TABLE B.1 (continued)

NAME	SUBR	DESCRIPTION
YMMX	AGPLOT	maximum horizontal value for mean particle trajectories
YSB	AGEQD AGPLT	equivalent Gaussian horizontal standard deviation
YSMN	AGPLOT	minimum horizontal value for particle spread trajectories
YSMX	AGPLOT	maximum horizontal value for particle spread trajectories
YSV	AGEQD AGEQG AGPLT	vector: horizontal standard deviations
YVEC	AGGRD AGPLT AGRPF	vector: horizontal plotting entries
YVMN	AGPLOT	minimum horizontal value for centerline trajectories
YVMX	AGPLOT	maximum horizontal value for centerline trajectories
ZCB	AGEQD AGPLT	equivalent Gaussian vertical position
ZCV	AGEQD AGEQG AGPLT	vector: vertical particle mean positions
ZGMN	AGPLOT	minimum vertical value for ground deposition
ZGMX	AGPLOT	maximum vertical value for ground deposition
ZMAX	AGEQG AGGRD AGPLOT	vertical axis plot scale maximum
ZMIN	AGEQG AGGRD AGPLOT	vertical axis plot scale minimum
ZMMN	AGPLOT	minimum vertical value for mean particle trajectories
ZMMX	AGPLOT	maximum vertical value for mean particle trajectories
ZSB	AGEQD AGPLT	equivalent Gaussian vertical standard deviation
ZSMN	AGPLOT	minimum vertical value for particle spread trajectories
ZSMX	AGPLOT	maximum vertical value for particle spread trajectories
ZSV	AGEQD AGEQG AGPLT	vector: vertical standard deviations

TABLE B.1 (continued)

NAME	SUBR	DESCRIPTION
ZVEC	AGGRD AGFLT AGRPF	vector: vertical plotting entries
ZVMN	AGPLOT	minimum vertical value for centerline trajectories
ZVMX	AGPLOT	maximum vertical value for centerline trajectories

APPENDIX C: Using AGDISP/AGPLOT

Normal operation on the Fort Collins computer system requires the establishment of an input file on unit 4 (with an @USE_4.,INPUTFILE.), a plot file on unit 8 (with an @USE_8.,PLOTFILE.) and a printer file on unit 9 (with an @USE_9.,PRINTFILE.). Terminal output is written to unit 6. This setup is accomplished for an @RUN with the invoking of @ADD_AGDISP.INITIAL. (those features are detailed in Ref. 2). Multiple ground deposition plots (invoking menu option 5 in AGPLOT) require manipulation of several files, and suggest the importance of running AGDISP in batch. This appendix addresses these two issues.

Up to sixteen curves may be plotted on the same multiple deposition plot. For illustration purposes only, we will examine the procedure involved to compute and plot three files, with the generalization obvious. Table C.1 shows the processing blocks involved. It is assumed that the temporary plot files, PLOT1 and PLOT2, have not been previously assigned; otherwise a simple @ASG,A would be used for each file.

Since the input data is read from INPUTFILE, the editor is used to set up the first set of data. Block 1 is then invoked. The editor is entered to modify INPUTFILE for the second set of data, and Block 2 is invoked. The third set of data is set, and Block 3 is invoked. Note that after Block 3, all plot data is saved, the first set in PLOT1, the second in PLOT2, and the last in PLOTFILE. AGPLOT will first look to PLOTFILE for data; therefore, we need to establish a link to our other files using Block 4. At this point, we invoke AGPLOT with Block 5.

Under option 5, AGPLOT will first request the mass fraction for the current data set (the data in PLOTFILE), then attempt to open units 11, 12, 13, etc. until the mass fraction total meets or exceeds unity. In this example, the second file opened will be PLOT1 and the third file opened will be PLOT2. The mass fraction should now equal unity, and AGPLOT will request nozzle flow rate, deposition scale type, etc. to complete the plot. A legend plot will correlate particle size and mass fraction with the specific curves used to plot the deposition.

It seems clear that the batch processor could be used to do the work of Blocks 1, 2, and 3 in a delayed or overnight job. Such a set up could be established for the three deposition runs discussed above by constructing a batch file (called BATCHFILE) with the contents of Block 6 shown in Table C.2. Here we assume that the initial file assignments have already been made (following those shown in Table C.1) so that errors will be discovered interactively and not in batch. To run in batch requires the establishment of separate input files (rather than simple editing of INPUTFILE) that can be recovered to run AGDISP. The process involves copying the relevant data into INPUTFILE, running AGDISP, and copying the PLOTFILE results for later processing. In the example shown here, PLOT1, PLOT2, and PLOTFILE will again hold the results needed to invoke AGPLOT to plot multiple ground deposition.

BATCHFILE is invoked by entering the interactive commands shown in Block 7. A separate @RUN must be typed to the screen, with an @PASSWD card, and BATCHFILE added to the runstream with @ADD. An @FIN completes the job deck.

Note that with this procedure, Block 7 can be used for any batch file desired, but it must be typed in interactively. Block 6 can be modified with the editor for any specific purpose. Since no checks are made until runtime, there can be no mistakes in the setup and in BATCHFILE if the run is to be successful.

A terminal output file is created for every batch job run at Fort Collins. This file essentially contains the information printed to the screen by the system and by AGDISP. To recover this file (to see whether the batch run was successful, for example), the user would invoke Block 8 at the point where the system requests USERID/PASSWORD. With an asterisk in front of the userid/password, the system will permit the @@SEND command to recover results. The terminal then becomes inactive, and the user may invoke @RUN to start an interactive job and eventually invoke AGPLOT to plot results.

In all of the above examples, the PRINTFILE was overwritten and not saved. To save printed results for each input file would require additional statements similar to the statements for PLOTFILE.

Table C.1: Interactive Processing of Three Deposition Files

Block 1:

```
@XQT_AGDISP.GODISP
@ASG,UP_PLOT1.,F/100/TRK/500
@COPY_PLOTFILE.,PLOT1.
```

Block 2:

```
@XQT_AGDISP.GODISP
@ASG,UP_PLOT2.,F/100/TRK/500
@COPY_PLOTFILE.,PLOT2.
```

Block 3:

```
@XQT_AGDISP.GODISP
```

Block 4:

```
@USE_11.,PLOT1.
@USE_12.,PLOT2.
```

Block 5:

```
@XQT_AGDISP.GOPLOT
```

Note: An underline _ denotes a single blank space.

Table C.2: Batch Processing of AGDISP

Block 6:

```
@ADD_AGDISP.INITIAL

@ASG,A_INPUT1.

@COPY_INPUT1.,INPUTFILE.

@XQT_AGDISP.GODISP

@ASG,A_PLOT1.

@COPY_PLOTFILE.,PLOT1.

@ASG,A_INPUT2.

@COPY_INPUT2.,INPUTFILE.

@XQT_AGDISP.GODISP

@ASG,A_PLOT2.

@COPY_PLOTFILE.,PLOT2.

@ASG,A_INPUT3.

@COPY_INPUT3.,INPUTFILE.

@XQT_AGDISP.GODISP
```

Block 7:

```
@RUN,P/B_W51FMT,1152017501/5238JKENISTO,FSCDI

@PASSWD_SI

@ADD_BATCHFILE.

@FIN
```

Block 8:

```
*5238JKENISTO/SI

@@SEND
```

APPENDIX D: Atmospheric Turbulence Level

The second entry on card 0050 is the maximum value of background turbulence q^2. This value influences the growth of the variance about the mean particle motion, and the standard deviation of the deposition. The crosswind inputs on card 0028 also produce a turbulence level that gets added to the card 0050 level, since a logarithmic profile generates a turbulence level of

$$q^2 = 0.845 \, [U/\ln(z_h/z_o)]^2$$

where U is the velocity at height z_h with surface roughness z_o. Under locally neutral atmospheric conditions, the total wind velocity U_t at z_h would be used to compute q^2_t, by the above formula. For that portion of the wind in the crossplane, AGDISP will compute q^2, and the entry on card 0050 should be the difference $q^2_t - q^2$. If the atmosphere is calm, the turbulence level may be taken as 0.0.

For atmospheric conditions other than neutral or calm, estimates of turbulence levels may be obtained by using stability categories (Ref. 6 & 7). Table D.1 presents these averaged atmospheric categories as a function of surface wind and temperature inversion, while Table D.2 gives the range in values for turbulence as a function of surface wind and stability category. Selecting the simulation time-of-day and surface conditions permits the selection of the stability category, A through G. This category then provides for the selection of turbulence values consistent with the stability.

Table D.1: Stability categories in terms of wind speed, insolation and state of sky (from Ref. 6)

Surface wind speed (m/sec)	Insolation			Night	
	Strong	Moderate	Slight	Thinly overcast or>4/8 low cloud	<3/8 cloud
<2	A	A-B	B	G	G
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Notes:

1) for A-B take average of values for A and B etc.

2) strong insolation corresponds to sunny midday in midsummer, slight insolation to similar conditions in midwinter. Night refers to the period from 1 hr before sunset to 1 hr after dawn. The neutral category D should also be used, regardless of wind speed, for overcast conditions during day or night, and for any sky conditions during the hour preceding or following the night as defined above.

Table D.2: Turbulent intensities near ground level (from Ref. 7)

STABILITY CATEGORY		q^2/U^2
A	extremely unstable	0.365 - 1.2
B	moderately unstable	0.145 - 0.365
C-D-E	near neutral	0.025 - 0.145
F	moderately stable	0.015 - 0.025
G	extremely stable	0.0 - 0.015

NATIONAL AGRICULTURAL LIBRARY
1023071904

NATIONAL AGRICULTURAL LIBRARY
1023071904